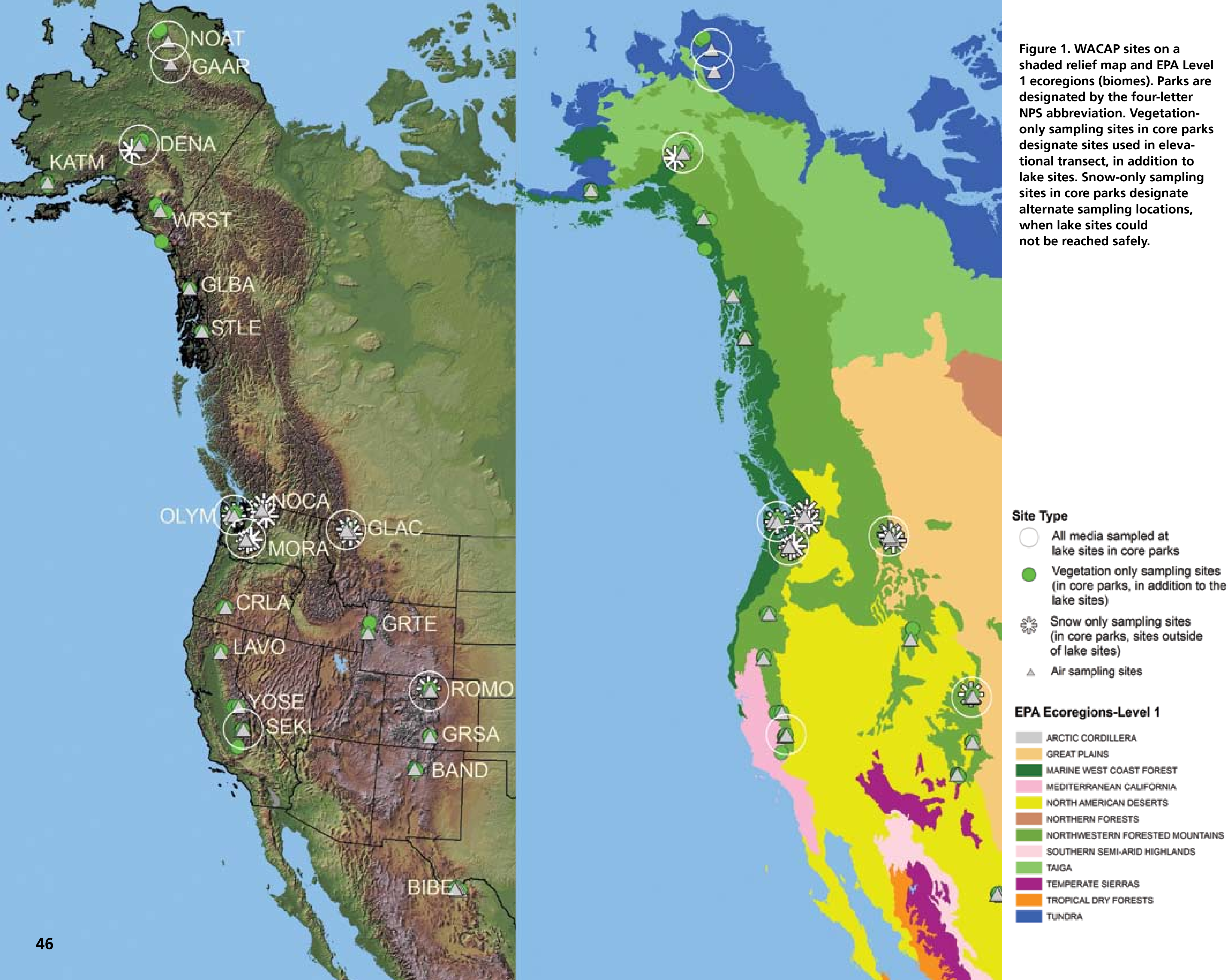

Figure 1. WACAP sites on a shaded relief map and EPA Level 1 ecoregions (biomes). Parks are designated by the four-letter NPS abbreviation. Vegetation-only sampling sites in core parks designate sites used in elevational transect, in addition to lake sites. Snow-only sampling sites in core parks designate alternate sampling locations, when lake sites could not be reached safely.

Evaluating Airborne Contaminants in Alaska National Parks: The Western Airborne Contaminants Assessment Project

By Dixon H. Landers, Tamara Blett, Marilyn M. Erway, and Linda Geiser

Background

Some of the world's most toxic persistent chemicals are carried in air masses, from sources as far away as Europe and Asia, and as close as local farmer's fields or a regional coal fired power plant. The objective of the Western Airborne Contaminants Assessment Project (WACAP) was to examine a broad suite of airborne contaminants in national park ecosystems using a network of eight "core" parks (Noatak, Gates of the Arctic, Denali, Glacier, Olympic, Mount Rainier, Rocky Mountain, and Sequoia) in the western U.S. In addition, 12 "secondary" parks were sampled for vegetation and air (*Figure 1*) to strengthen the spatial understanding of this issue. The National Park Service (NPS) is concerned about airborne contaminants because they can pose serious health threats to wildlife and humans, as some of these compounds tend to "biomagnify" in food webs. This means that some contaminants can be tens to thousands of times more concentrated in higher food web levels (i.e. fish) than in snow or water or the base of food webs (i.e algae, insects). Biological effects of airborne contaminants can include impacts on reproductive success, growth, behavior, disease, and survival of fish, wildlife, and humans, if these compounds accumulate to toxic levels.

The NPS initiated this project in 2002 because:

- Potential risk to park resources was identified from preliminary studies in the Arctic and other high elevation or high latitude areas, but little information about potential impacts of toxics on national park resources was known.
- There was concern about subsistence-based populations in Alaska who consume foods that could be bioaccumulating toxic compounds and elements.
- Parks contain relatively undisturbed and near pristine natural systems that can serve as early warning sites for the rest of the continent.
- NPS responsibilities and legal mandates are to protect ecosystems "unimpaired" for future generations (Organic Act).

This six-year WACAP project was designed to: 1) determine if contaminants are present in western national parks; 2) determine where contaminants are accumulating (geographically and by elevation); 3) determine which contaminants pose a potential ecological threat; 4) determine which indicators appear to be the most useful to address contamination; and 5) determine the sources for contaminants measured at the national park sites.

Scientific Partnerships

This project is likely unique for an NPS sponsored project because of its large scope, scale, duration, and number of cooperators. We held a series of workshops in 2001 that identified the need for more information about the risk of airborne toxics in parks. Following these workshops, Dr. Dixon Landers, an Environmental Protection Agency (U.S. EPA) scientist, was selected to identify and lead a transdisciplinary team of researchers to conduct a large scale integrated study on airborne contaminants in western national parks. Researchers from the U.S. Geological Survey, U.S. Forest Service, University of Washington, and Oregon State University worked with the NPS and U.S. EPA on various aspects of this project. Donald Campbell of the USGS coordinated the snow sampling and analyses. The Pacific Northwest Cooperative Ecosystem Studies Unit (CESU) has been instrumental in facilitating the participation of scientists in this project. At Oregon State University, Dr. Staci Simonich led the organic chemistry laboratory analysis and interpretation effort to determine the presence and concentrations of toxic contaminants in air, water, sediment, snow, vegetation, fish, and moose. Many of the analytical methods were customized for WACAP; Dr. Simonich and a large number of post-doctoral students, graduate students, undergraduates, and laboratory technicians pioneered and published new techniques to conduct the WACAP research. Adam Schwindt, Dr. Carl Schreck (leader of the Oregon Cooperative Fish and Wildlife Research Unit), and Dr. Michael Kent (director of the Center for Fish Disease Research at Oregon State University) have been key partners in looking at physiological,

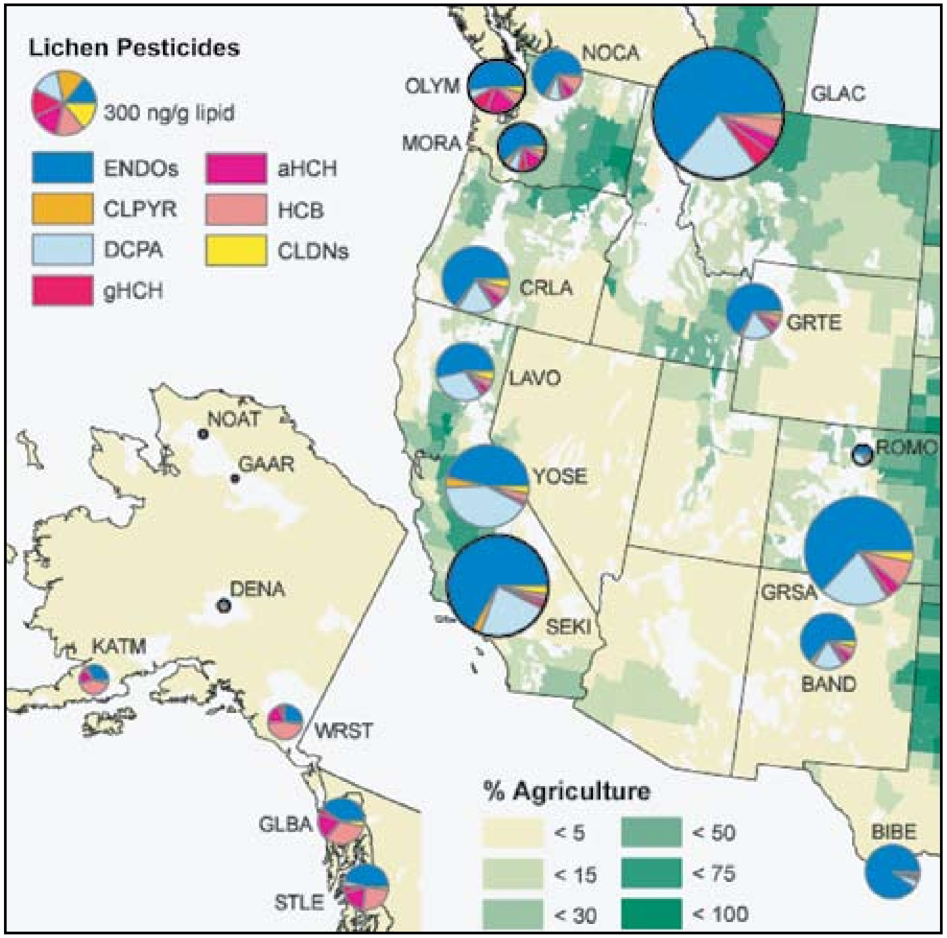

Figure 2. Pesticide concentrations (ng/g lipid) in lichens from core and secondary WACAP parks overlaid on a map of agricultural intensity (US Department of Agriculture, National Agriculture Statistics Service 2002). Circle area is proportional to total pesticide concentration. White shading indicates national forests or parks. Current-use pesticides endosulfan and dacthal dominate pesticide concentrations in parks in the conterminous United States, where most agriculture occurs. Historic use pesticides comprise a relatively larger fraction of total pesticide concentrations in Alaska. Sites outlined in black are core parks. Abbreviations for pesticide groups are endosulfans (ENDOs), chlorpyrifos (CLPYR), dacthal (DCPA), g-HCH and a-HCH (gHCH and aHCH), hexachlorobenzene (HCB), and chlordanes (CLDNs).

hormonal, and chemical characteristics of fish in the study lakes. Dr. Daniel Jaffe, Professor of Atmospheric and Environmental Chemistry at the University of Washington, analyzed complex atmospheric transport patterns that carry airborne contaminants into western national parks. These university scientists, along with other scientists from federal agencies, developed a unique integrative partnership through implementation of the project. For example, field data collection required approximately 2,000 pounds of scientific equipment and supplies to be transported by helicopter, floatplane, pack animals, and research staff into remote watersheds before the two week process of sample collection in each park could begin. Investigators also collaborated on development of data analysis, results, and publications; resulting in products where the whole is really more than a sum of the "parks".

Roadmap for Success

There are a few key elements that have made this project successful. 1.) Experienced and widely recognized scientists were selected to provide their expertise in designing and implementing the project. The CESU process provided an avenue to select those researchers with proven track records in publishing their work, and experience in working as part of an interdisciplinary team. 2.) A detailed, written research plan and quality assurance and quality control plan were developed with input from all scientists involved, and the research plan was peer-reviewed by an external, distinguished panel of subject matter experts. 3) Leadership and accountability was ensured by setting up a "Science Project Leader" and an "NPS Project Manager" to keep the project moving forward, facilitate integration among disciplines, receive feedback from NPS clients, and provide a mechanism for decision making. 4.) Avenues of communication such as a project web site, semi-annual investigators meetings, posters, and annual fact sheets helped keep everyone informed.

Results

Scientists involved with WACAP have now completed the collection, analysis and interpretation of all WACAP samples, and the WACAP Final Report is expected to be published on the Web in February, 2008. The final data base is scheduled to be published on the web by July 1, 2008. First, let's examine what we found out with respect to the objectives that drove all aspects of the study.

1.) Are contaminants present in western national parks? The answer to this question is an unqualified yes. We discovered scores of various semi-volatile organic compounds that we classified into historic use pesticides, current use pesticides, industrial/urban use compounds, and combustion by-products. Some of these have been banned for decades, while others are still in use in the United States or in Mexico and/or Canada. We also found selected metals such as mercury, lead and cadmium that were elevated over natural levels in some parks. Generally these contaminants were at concentrations below levels of concern raised by various government bodies (*Figure 1*).

2.) If present, determine where contaminants are accumulating (geographically and by elevation). We determined that some contaminants followed a pattern that suggests the chemical was easily transported, based on its physical and chemical properties, to high elevation and high altitude locations, which tend to be colder than most other places in a locality. We also found different rates of accumulation in the various environmental components we sampled, depending on the time over which the particular environmental component integrated and its own chemical characteristics. Snow and fish, for example had widely different contaminant concentrations and contaminant types. This difference is because snow represents only those contaminants deposited via several months of winter precipitation, whereas fish integrate contaminants over their lifetime and can live for decades (*Figure 2*).

3.) If present, determine which contaminants pose a potential ecological threat. Dieldrin, p,p'-DDE, and mercury were present in some fish at concentrations that exceeded established health thresholds for piscivorous fish and mammals, including humans. In Alaska, the average mercury concentration of the fish collected from Burial Lake in Noatak National Preserve, and some fish from Matcharak Lake in Gates of the Arctic National Park and Preserve, exceeded the U.S. Environmental Protection Agency (U.S. EPA) human contaminant health threshold (see *Figure 3*). All four lakes sampled in Alaska (Burial, Matcharak, and Wonder and McLeod lakes in Denali National Park and Preserve) had concentrations of dieldrin in some fish that exceeded the U.S. EPA human contaminant health threshold for subsistence fishing. Current use pesticides were generally undetected or very low in Alaska systems, but concentrations of historic use pesticides in Alaska parks were often similar to the concentrations in parks in the lower 48 states.

4.) Determine which indicators appear to be the most useful to address contamination. It appears that fish and sediments are the two indicators that, in combination, provide the most useful information regarding the numbers and types of contaminants, the long term history of exposure, the effects of bioaccumulation and the direct linkage to piscivorous components of the food webs.

5.) If present, determine the source of the air masses most likely to have transported contaminants to the national park sites. The source of most contaminants in the majority of sites in the lower 48 states appeared to be regional or local, with strong evidence of the importance of regional industrial and agricultural activities. In Alaska, given the greatly reduced occurrence of industrial and agricultural activities, the sources appear to be primarily long range transport and global background for contaminants like mercury and SOCs.

We found a long list of current and historic use contaminants in all parks

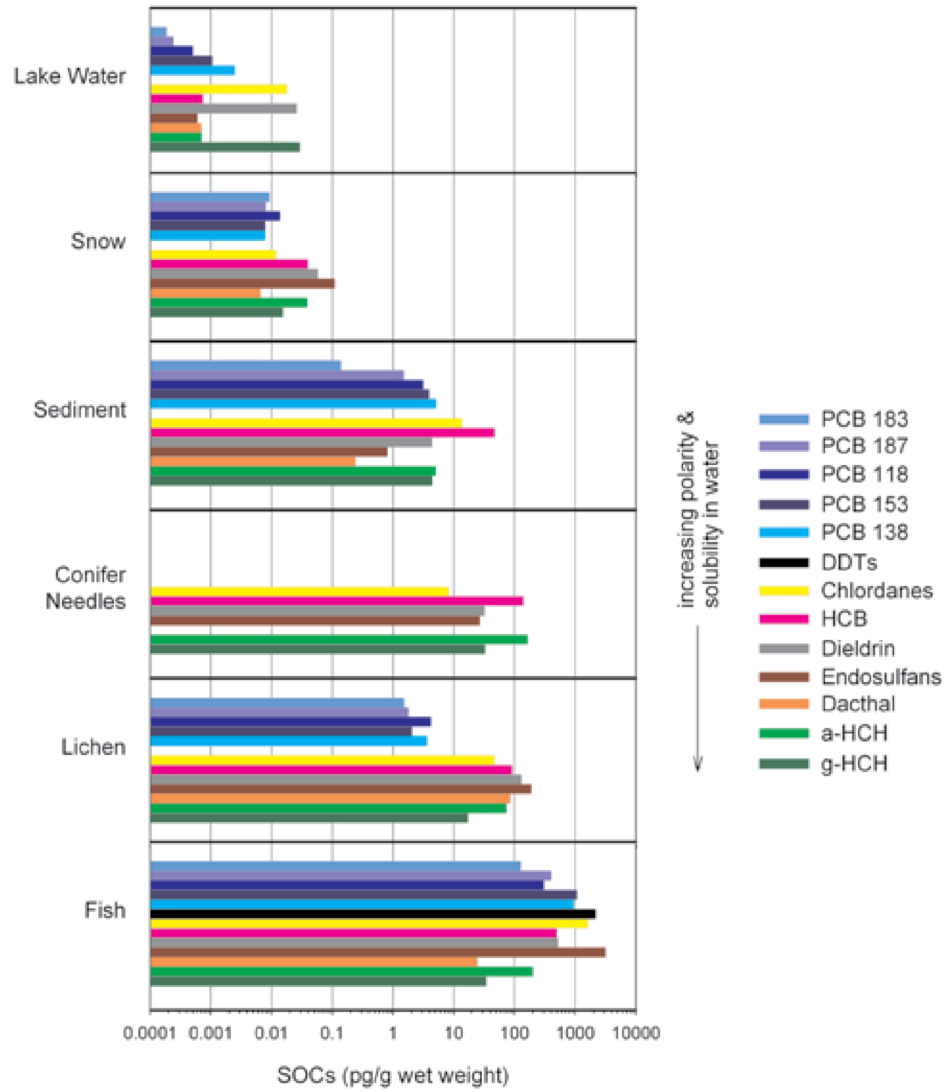

Figure 3. Comparison of patterns of semi-volatile organic compound (SOC) accumulation in lake water, snow, sediment, conifer needles, lichens, and fish from Wonder Lake in Denali National Park and Preserve. SOCs are listed in order of increasing polarity and solubility in water. The relative magnitude of the differences in concentrations is lake water, snow < sediment, conifer needles, lichens < fish. A 4 to 6 order higher accumulation of SOCs is observed in biota relative to snow and lake water. For compounds with measurable levels of SOCs in both fish and sediments, fish tissue concentrations were 2 to 3 orders of magnitude higher. Lake water, snow, and vegetation had higher affinities for more polar compounds, whereas sediments and fish accumulated the less polar compounds to a greater extent.

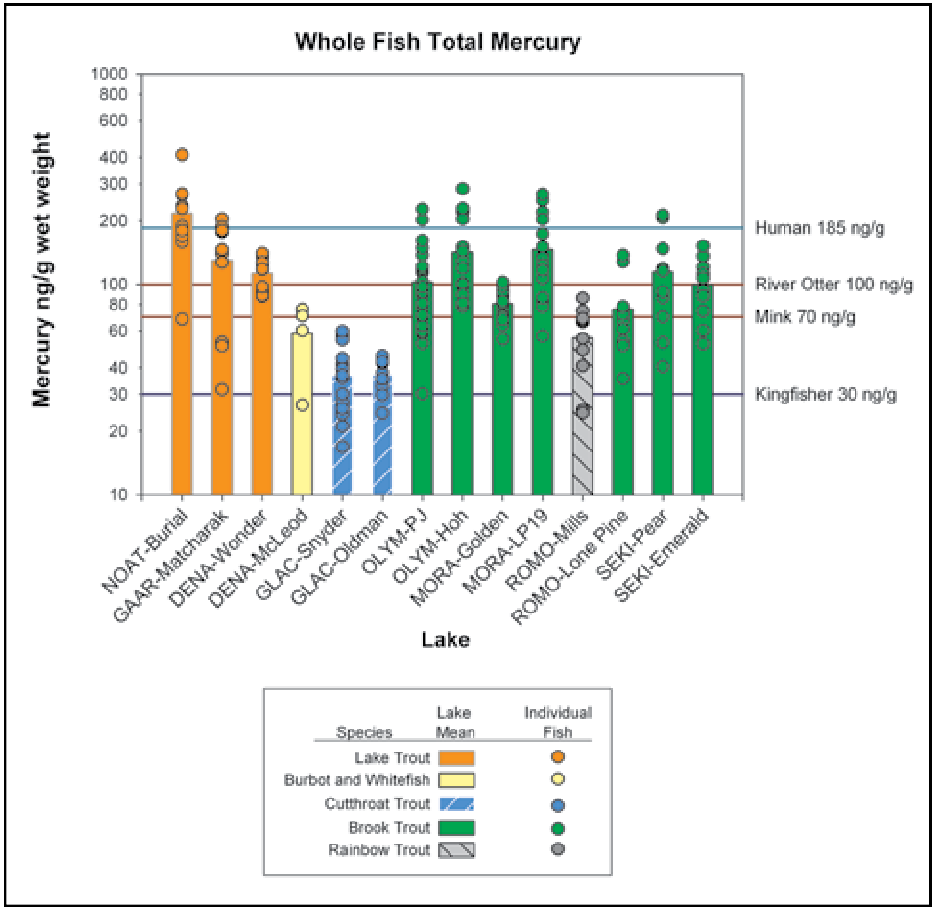

Figure 4. Total mercury for individual fish and means for lake sites, and contaminant health thresholds for various biota. The mean ng/g total mercury (Hg) in fish at NOAT exceeds the U.S. EPA human contaminant health threshold. The ng/g total mercury in some fish at GAAR (Matcharak), OLYM (PJ, Hoh), MORA (LP19), and SEKI (Pear) exceeds the U.S. EPA human contaminant health threshold. The mean ng/g Hg concentration in fish at all parks exceeds the kingfisher contaminant threshold, and the mean at seven lakes exceeds all wildlife thresholds—NOAT (Burial), GAAR (Matcharak), DENA (Wonder), OLYM (PJ, Hoh), MORA (LP19), and SEKI (Pear). 95-100% of mercury in fish is methyl-Hg (*Bloom 1992*) and 300 ng/g in the fillet is equivalent to 185 ng/g wet weight whole body methyl-Hg (*Peterson et al. 2007*). The human threshold is 300 ng/g wet weight (*USEPA 2001*), and is based on methyl-Hg in the fillet for a general population of adults with 154 pounds (70 kg) body weight and 0.0386 pounds (0.0175 kg) fish intake per day. Contaminant health thresholds in piscivorous animals (wildlife) are based on 100% fish in the diet for whole body total mercury, as determined by Lazorchak et al. (2003). Data are plotted on a log10 scale; the y-axis starts at 10 ng/g.

Figure 5. McLeod Lake sunrise

but generally at concentrations below levels of concern raised by various government and scientific sources. Current use pesticides are the most abundant group of compounds we have found in three years of annual snow sampling, and these compounds appear to be strongly related to regional agricultural activities in proximity to the parks (*Hageman et al. 2006*). Historic use chemicals such as PCBs (banned in the U.S.) show similar, low concentrations in fish from all of the WACAP primary parks. However, there is evidence in some parks that fish are demonstrating a physiological response to chemical stressors. In most parks, accumulations of debris scavenging cells (macrophage aggregates), which can indicate exposure to degraded environments, are associated with mercury, fish age (*Schwindt et al. 2008*), and poor nutrition. In Rocky Mountain and Glacier National Parks, scientists observed feminization of some male trout possibly in response to man-made compounds that mimic the female sex hormone estrogen (*Schwindt et al. 2007*). Mercury flux to the watersheds in the western national parks is dominated by mercury derived from human activities such as coal burning and metal smelting, as well as global background concentrations for this element. The mercury flux to the Alaska parks is approximately one-fourth that for the parks in the lower 48, yet the mean fish concentrations in some Alaska lakes are significantly higher (*Figure 3*). This finding appears to be due to watershed, lake and food web characteristics in the Alaska systems that efficiently bioaccumulate mercury in the top aquatic predators—fish. The WACAP final report fully documents these and other findings to inform future management decisions relating to the protection of the natural resources in our national parks. Several WACAP related articles have already been published in peer-reviewed literature, and more are expected in 2008.

What Can Be Done About Toxics in National Parks?

The information gathered as a part of this multi-agency partnership project will be of great value to the NPS because of the diversity of sensitive ecosystems that we manage. Specific uses or management actions in response to the WACAP results will be formulated over the coming months.

One of the key accomplishments of WACAP is to inform the NPS and the public about the presence and potential effects of toxic compounds in national parks. To that end, the interest in the project by the national and local media has been keen, and numerous articles have already been published in online and print newspapers across the country. A "WACAP Final Report To Parks" session took place at the George Wright Society meeting in St. Paul, Minnesota in April 2007. The NPS believes that the problems with toxic compounds identified by the WACAP researchers in parks can be used to aid the development of solutions through collaboration with regulatory agencies and stakeholders (domestically) and/or in international diplomatic arenas.

Disclaimer

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Figure 6. Water sampling at Wonder Lake

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